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Dear Sirs

PCT Application PCT/GB 03/04499
WesternGeco Seismic Holdings Limited et al

In response to the first written opinion on the above application I file herewith a set of amended claims 1-43 to replace the claims currently on file.

Claim 1 has been amended to specify that the sources provide a "positional signal for the determination of the position and depth of the or each seismic sensor". In the embodiment of figure 1(B), for example, the seismic cable 105 is deployed on the sea floor 112. In order to enable accurate processing of seismic data acquired at one of the sensors 115 on the seismic cable 105, it is not sufficient to know the two-dimensional position (i.e., the x- and y- coordinates) of the sensors 115 relative to the seismic source 114. It is also necessary to know the vertical distance between the seismic source 114 and the seismic sensors 115, and this requires that the depth of the seismic sensors is determined. The embodiment of figure 1(B) therefore uses three (or more) sources of positioning signals, and this allows the full three-dimensional position (that is, the two-dimensional position and the depth) of each seismic sensor 115 on the cable to be determined.

The invention may also be used to determine the position and depth of a seismic sensor while the cable is being deployed on or retrieved from the seabed, to monitor the change in depth of the sensor during deployment or retrieval. Again, this cannot be done by simply measuring the two-dimensional position of the sensor but requires determination of the depth of the seismic sensor.

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Claim 13 has been amended to depend from claim 1.

Claim 19 has been amended in a similar manner to claim 1.

Claim 28 has been amended to depend from claim 19.

Finally, claims 31, 34, 36 and 40 have been amended to refer back to an apparatus as defined in any one of claims 1 to 9.

The amendments to claims 13, 28, 31, 34, 36 and 40 have been made in response to section 1.2 of the written opinion, to facilitate issuance of a favourable IPER. These amendments do not constitute abandonment of the subject matter of the original claims 13, 28, 31, 34, 36 and 40.

It would appear that the most relevant of the documents cited in the written opinion is D6 (US-4 376 301). However, this document is directed solely to determining the two-dimensional position of a marine streamer towed behind a survey vessel. As is described in the introduction of D1, the streamer is submerged below the water surface through the action of depth controllers provided along the length of the streamer – see column 1, lines 38-41. The depth of the sensors (hydrophones) disposed along the cable will therefore be known, as is acknowledged in D6 at column 4, lines 35-40, since the depth of the sensors is determined by the setting of the depth controllers.

The amended claims 1 and 19 are therefore novel over D6.

It is further submitted that applying the method of D1 to measuring the depth of a seismic sensor is not obvious, contrary to the suggestion made in section 3 of the written opinion. The use of an apparatus or method as defined in claim 1 or 19 to measure the depth of a seismic sensor disposed on the seabed, or in course of deployment on or retrieval from the seabed, is not suggested in the prior art; claims 1 and 19 are not made obvious simply because it is known to deploy a seismic sensor on the seabed.

In particular, applying the system of D6 to the determination of depth of a seismic sensor disposed on the seabed is not an obvious measure, for a number of reasons. The seabed has structure, and the cross-currents vary with depth in the sea, so that the position of a seismic sensor on a sea-floor cable is much less well known during deployment, and when it is disposed on the sea-floor, than is the position of a towed seismic streamer. In contrast, measuring the difference (or "feather angle") between the course of a survey vessel and the position of a towed seismic streamer is relatively straightforward. A skilled person would therefore not have considered applying the method of D6 to measuring the position and depth of a seismic sensor that was disposed on, or that was in process of deployment onto, the sea-floor.

Furthermore, the system described in D6 is unable to measure the depth of a seismic sensor. D1 comprises two sources of positioning signals that are symmetrically disposed about the survey vessel, and so are both at the same depth. The positioning signals of D6 cannot provide any information about the depth of the hydrophones on the streamer. D6 makes use of the prior knowledge of the depth of the sensors that is available in the case of a towed seismic streamer – where the party carrying out the survey will set the streamer to run at a pre-determined depth below the sea surface. However, this prior knowledge is simply

unavailable in the case of a sea-bed cable that is positioned on, or is in process of deployment onto, the sea-floor.

It will also be noted that in D6 the return signal from the sensors passes back to the towing vessel through the streamer, as stated at column 3, lines 57-59. This is not possible in the case of a sensor on a sea-floor cable that has been laid on the sea-floor.

As far as the other citations are concerned, D1 again relates to a towed hydrophone cable which is maintained at a fixed depth within the water (as shown in figure 3, for example). D1 is again directed to measuring the "feather angle" of the hydrophone cable, and does not disclose or suggest using the positioning signals to determine the depth of the hydrophones.

It is further pointed out that D1 does not disclose the use of positioning signals that are intrinsically distinguishable from seismic survey signals. D1 refers to the positioning signals being detected "in those periods wherein the echo sound waves from the bottom are on a relatively inactive level" – see page 7, lines 15-17 – and this indicates that the positioning signals cannot be distinguished from the seismic survey signals. If the positioning signals could be distinguished from the seismic survey signals, there would be no need to limit detection of the positioning signals to periods where the seismic survey signals were inactive.

D2 again relates to determination of the location of a submerged marine streamer 20 that is towed behind a seismic survey vessel 18. Again, the depth of the seismic cable will be known, and D2 is again directed to determining the lateral distance between the path of the survey vessel and the streamer – see page 1, lines 38-51. D2 does not relate to determination of the depth of a seismic cable when it is disposed on, in process of deployment on, the sea-floor.

Furthermore, D2 does not disclose receiving the positioning signals at seismic sensors in the seismic cable. The seismic cable in D2 is provided with hydrophones for receiving seismic survey signals, as stated at page 1, lines 10-13 and at page 2, line 40. Acoustic receivers 34 for receiving positioning signals are provided in the cable **in addition to** the hydrophones – see page 2, lines 43-45. Thus, in D2 the positioning signals are not provided to the seismic sensors but are provided to additional sensors provided in the seismic cable specifically to receive the positioning signals.

D2 again does not disclose that the positioning signals are distinguishable from seismic survey signals. The passage at page 2, lines 59-60 discloses only that the frequencies at which the transponders 10, 12, 14 emit are different from one another. There is no information in D2 as to how the frequencies at which the transponders 10, 12, 14 emit compare with the frequency range of the seismic signal.

Finally, D5 discloses a piezoelectric transducer that can be incorporated in a seismic streamer, at the position T1 to T6 shown in figure 1. The transducer may be used as either a transmitter or a receiver (column 2, lines 50-55). In the example of figure 1, the transducers in the central streamer are used as transmitters and the transducers in the outer streamer are used as receivers in determining the lateral positions of the three seismic streamers relative to one another.

There is no disclosure that the transducers of this citation act as a seismic sensor. These transducers are provided in the seismic cables in addition to seismic sensors. Thus, the

positioning signal generated by the transducers in the central streamer is not directed to a seismic sensor.

Furthermore, the transducers are deployed in the streamers. There is therefore no disclosure of a source of a positioning signal that is "deployed in a manner structurally independent of the seismic sensors" – the seismic sensors and the transducers are both deployed in the streamers.

Finally, D5 again relates to towed seismic streamers that will be at a known depth below the sea-surface. D5 is directed to measuring the lateral distance between one streamer and an adjacent streamer. There is no disclosure or suggestion of measuring the depth of seismic sensors in the streamers.

It is therefore submitted that the amended claims are novel and inventive over the cited prior art.

It is believed that this application is now in order for a positive IPER to be issued. If, however, there should be any outstanding objections relating to patentability, I request that a further written opinion is issued.

Yours faithfully
Marks & Clerk

Dr A. M. Suckling

CLAIMS

1. An apparatus comprising:

at least one seismic sensor; and

a plurality of sources deployed in a manner structurally independent of the or each seismic sensor and adapted to provide a positional signal for the determination of the position and depth of the or each seismic sensor, the positional signal being distinguishable from a seismic survey signal to the or each seismic sensor.

2. The apparatus of claim 1, wherein the sources are adapted to provide the positioning signal at a frequency outside the bandwidth of the seismic survey signal.

3. The apparatus of claim 2, wherein the sources are adapted to provide the positioning signal at a frequency above the bandwidth of the seismic survey signal.

4. The apparatus of claim 3, wherein the sources are adapted to provide the positioning signal having a frequency bandwidth.

5. The apparatus of claim 4, wherein the frequency bandwidth is approximately 700 Hz to 2000 Hz.

6. The apparatus of claim 4, wherein the frequency bandwidth is approximately 1500 Hz to 4500 Hz.

7. The apparatus of claim 1, wherein the plurality of sources comprises between two and five sources, inclusive.

8. The apparatus of claim 7, wherein the plurality of sources comprises three sources.

9. The apparatus of claim 1, wherein the plurality of sources are piezoelectric sources.

10. The apparatus of claim 1, further comprising a signal processing unit adapted to determine the position of the or each seismic sensor from the received positioning signal.

11. The apparatus of claim 10, wherein the signal processing unit is adapted to determine the position of the or each seismic sensor using a plurality of propagation times from the plurality of sources to the at least one seismic sensor.

12. The apparatus of claim 11, wherein the signal processing unit is adapted to determine the position of the or each seismic sensor by triangulation using the plurality of propagation times from the plurality of sources to the at least one seismic sensor.

13. An apparatus as claimed in claim 1 wherein at least one seismic sensor is deployed on a seabed.

14. The apparatus of claim 13, wherein the sources are adapted to provide the positioning signal at a frequency outside the bandwidth of the seismic survey signal.

15. The apparatus of claim 14, wherein the sources are adapted to provide the positioning signal at a frequency above the bandwidth of the seismic survey signal.

16. The apparatus of claim 15, wherein the sources are adapted to provide the positioning signal having a frequency bandwidth.

17. The apparatus of claim 16, wherein the frequency bandwidth range is approximately 700 Hz to 2000 Hz.

18. The apparatus of claim 17, wherein the frequency bandwidth range is approximately 1500 Hz to 4500 Hz.

19. A method for determining a position of at least one seismic sensor capable of receiving a seismic survey signal, comprising:

transmitting a plurality of positioning signals from a plurality of sources deployed in a manner that is structurally independent of the or each seismic sensor, the positioning signals being distinguishable from the seismic survey signal;

receiving the positioning signals at the or each seismic sensor; and

determining the position and depth of the or each seismic sensor from the received positioning signals.

20. The method of claim 19, wherein transmitting the plurality of positioning signals comprises transmitting the positioning signals at a frequency outside the bandwidth of the seismic survey signal.

21. The method of claim 20, wherein transmitting the plurality of positioning signals comprises transmitting the positioning signals at a frequency above the bandwidth of the seismic survey signal.

22. The method of claim 21, wherein transmitting the plurality of positioning signals comprises transmitting the positioning signals at a frequency between 700 Hz and 4500 Hz.

23. The method of claim 22, wherein transmitting the plurality of positioning signals comprises transmitting a plurality of sweeps from 700 Hz to 2000 Hz.

24. The method of claim 22, wherein transmitting the plurality of positioning signals comprises transmitting a plurality of sweeps from 1500 Hz to 4500 Hz.

25. The method of claim 19, wherein determining the position and depth of the or each seismic sensors using the received signals comprises determining a plurality of propagation times from the sources to the or each seismic sensor using the received signals.

26. The method of claim 25, wherein determining the position and depth of the or each seismic sensor comprises determining the position and depth of the or each seismic sensors using the plurality of propagation times.

27. The method of claim 26, wherein determining the position and depth of the or each seismic sensor using the plurality of propagation times comprises determining the position and depth of the or each sensor by triangulation using the plurality of propagation times.

28. A method as claimed in claim 19 and comprising receiving the positioning signals at a plurality of seismic sensors deployed on a sea bed.

29. The method of claim 28, wherein transmitting the plurality of positioning signals comprises transmitting the positioning signals at a frequency outside the bandwidth of the seismic survey signal.

30. The method of claim 29, wherein determining the position of the seismic sensors using the received signals comprises determining a plurality of propagation times from the sources to the seismic sensors using the received signals.

31. A system, comprising:

an apparatus as defined in one of claims 1 to 9;

a vessel;

a seismic cable having the least one seismic sensor, wherein the seismic cable is deployed from the vessel;

a plurality of buoys; and

a signal processing unit adapted to determine the position of the seismic sensors from the received positioning signals; wherein at least one source is suspended beneath the survey vessel and the remainder are deployed on the buoy.

32. The system of claim 31, wherein the buoys are autonomous self-propelled buoys.

33. The system of claim 31, wherein the buoys are towed behind the survey vessel.

34. A system, comprising:

an apparatus as defined in one of claims 1 to 9;

a vessel;

a seismic cable having the at least one seismic sensor wherein the seismic cable is deployed from the vessel;

at least one boom coupled to the vessel; and

a signal processing unit adapted to determine the position of the sensors from the received positioning signals; wherein at least one source is coupled to the vessel and the remainder are coupled to the at least one boom.

35. The system of claim 34, further comprising an array of seismic cables having at least one sensor capable of receiving the seismic survey signal.

36. A system, comprising:

an apparatus as claimed in one of claims 1 to 9; and

a plurality of autonomous self-propelled buoys;

wherein the sources are coupled to the self-propelled autonomous buoys.

37. The system of claim 36, wherein the sources are suspended beneath the autonomous self-propelled buoys.

38. The system of claim 36, further comprising a signal processing unit adapted to determine the position of the seismic sensors using the received positioning signals.

39. The system of claim 36, wherein the seismic sensors are deployed on a seismic cable coupled to the vessel.

40. A system, comprising:

an apparatus as claimed in any of claims 1 to 9;

a first vessel;

a seismic cable having the at least one seismic sensor, wherein the seismic cable is deployed from the first vessel;

a second vessel;

a plurality of buoys; and a signal processing unit adapted to determine the position of the seismic sensors from the received positioning signals; wherein at least one source is coupled to the first vessel, at least one source is coupled to the second vessel, and the remainder are deployed on the buoys.

41. The system of claim 40, wherein at least a portion of the buoys are deployed along a length of the seismic cable.

42. The system of claim 40, further comprising an array of seismic cables having at least one seismic sensor capable of receiving the seismic survey signal.

43. The system of claim 42, wherein at least a portion of the buoys are deployed among the array of seismic cables.